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Division of Agricultural Sciences

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The Tenth Report in a Series on
Efficiency in Fruit Marketing

ECONOMIES OF SCALE IN PEAR PACKING

B. C. French, L. L. Sammet, and R. G. Bressler

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FOREWORD

This is the tenth in a series of reports on costs and efficiency in the marketing of deciduous fruits. Previous reports have been concerned with particular phases of packing house operation. The present report deals with the more general problems of total plant costs such as the effect of scale of operation on costs and the combination of methods or technologies that give least costs for plants of given capacity rates of output and length of operating season.

The data pertaining to equipment capacities and rates of worker output on different jobs on which the cost relations are based were derived from studies of actual plant operations and analysis of accounting record data obtained during the 1950 packing season. Costs for both labor and equipment increased by about 16 per cent from 1950 to 1954. In this report, the original cost calculations have been adjusted to the 1954 price level.

These studies were made cooperatively by the Giannini Foundation of Agricultural Economics of the Agricultural Experiment Station, University of California, Berkeley, and the Agricultural Marketing Service, U. S. Department of Agriculture. They were made under authority of the Research and Marketing Act of 1946 (Research and Marketing Act, Title II). This Act provides for studies of the costs of marketing agricultural products in their various forms and through the various channels and is designed to foster and assist in the development of more efficient marketing methods, practices, and facilities for the purpose of bringing about more efficient and orderly marketing and reducing the spread between producer and consumer.

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ECONOMIES OF SCALE IN PEAR PACKING

B. C. French, L. L. Sammet, and R. G. Bressler[1]

INTRODUCTION

A casual survey of plants packing fresh pears in California reveals wide variation in methods and size or scale of operation. For example, at least five different methods are used to dump incoming fruit on conveyors to the grading tables; there are three types of packing equipment, five or more methods of distributing empty packing boxes, and three types of lidding machines. Plants vary in capacity from about 12,000 pounds of fruit handled per hour to over 75,000 pounds per hour.

In planning future development of their operations, packing plant managers face the problem of determining which of the possible combinations of methods and what scale of operations will lead to the highest level of efficiency. Managers usually are able to compare the costs of only a few of the alternatives available since a complete analysis would require familiarity with methods not used in their plants and with the operations and costs of plants of considerably different size.

This report is one of a series aimed at supplying packing house managers and owners with information of this type. Previous reports have dealt with small segments of the packing operation such as dumping, grading, and in-plant transportation.[2] The present report is concerned with the broader aspects of the entire "door to door" or in-plant process. It builds on the material of the previous publications to measure the impact of different types of organization and scale of operations on the total packing cost.

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[2] These reports are listed on the last page.

The first section of the report summarizes the combinations of methods that give the least cost for plants of any given capacity rate of output and length of operating season. Details of crew and equipment organization are given for illustrative plants, and the relation of cost to various rates of output is calculated for these plants. The second section is concerned with an analysis of the relationships between total costs and scale of operations and the use of these relations in planning future operations. The final section gives an indication of the potential cost reduction in the pear-packing industry if a substantial portion of the possible economies were achieved.

Data on labor and equipment utilization and costs were obtained in 15 California pear packing plants. Similar operations were also studied in eight California apple packing houses, and this provided additional data on some cost components. The 15 pear packing plants (from a total of about 74 in California) were selected from 6 of the major pear-producing districts--3 in the Sacramento district, 2 in Placer, 1 in El Dorado, 4 in Lake, 2 in Mendocino, and 3 in Santa Clara. They represent a wide range in total capacity, varying from less than 20,000 pounds per hour to about 75,000 pounds. Data concerning the costs of certain methods not actually observed in the sample of California pear and apple packing plants, but which appeared adaptable to these plants, were obtained in two Washington apple plants and from a separate study of grape packing. Data on the operation and costs of equipment were obtained from manufacturers as well as from the plant studies.

It should be emphasized that the cost relationships given in this report will differ from the accounting costs of individual plants. This is due to differences between the standardized rates for labor and other costs used as compared with rates actually paid in individual plants, to variations in the level of efficiency and percentage of plant capacity utilized, and to the effect of scale of operation and hours operated per season. Another important difference is that fixed costs for equipment are computed in this report by applying standardized cost rates to current replacement costs, while the fixed costs for equipment in individual plants reflect differences in the price level at the time of purchase and in the method of allocating equipment costs to each year's output.

TECHNOLOGIES AND PLANT ORGANIZATION

Plants packing fresh pears involve a number of different operating "stages." Each stage may consist of a single operation or a group of closely related operations. For example, one stage in pear packing is dumping fruit on conveyors

to the grading tables, grading is another stage, and lidding another. Other cost components not actually associated with specific stages include overhead items such as office and administrative costs and miscellaneous plant labor such as janitors.

The kinds of operations performed in packing fresh pears and their relation to the flow of products and materials are illustrated in Figure 1. For the purposes of this study, these operations are classified in 16 different plant stages or cost components. These are as follows: (1) dumping, (2) grading, (3) packing, (4) direct clerical-type jobs such as stamping, tallying, checkweighing, and placing pads on boxes, (5) lidding, (6) car- and truckloading, (7) boxmaking and labeling, (8) empty packing box and materials supply, (9) packaging cannery and cull fruit, (10) in-plant transportation of fruit and materials, (11) general plant supervision, (12) miscellaneous plant labor, (13) office and administrative costs, (14) building costs and costs of equipment not associated with specific stages, (15) miscellaneous general expenses such as office supplies, and (16) costs of accounting to growers for fruit delivered to the packing house.

For a number of these stages, there are several alternative methods or "technologies" which may be used to perform the required operations. This means that it is possible to organize plants in many different ways. For each size of plant and set of operating conditions, there will be a particular organization that gives lower costs than any other. To find these most efficient organizations involves, first, estimating cost standards based on reasonably efficient performance for all of the alternative technologies available at each plant stage or for each cost component; and, second, combining these alternatives into all feasible types of organization and selecting the organizations that are most efficient for any rate of output and length of season.[1]

Simplifications and Assumptions

In seeking the least-cost combinations of technologies desired in this analysis, a number of simplifications were adopted. These are as follows:

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[1] Details of these cost standards for most stages are given in the reports listed on the last page. A technical discussion of the specific procedures involved in combining the stage and component costs and summary details on cost standards for all stages may be found in French, B. C., L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia, in Press.

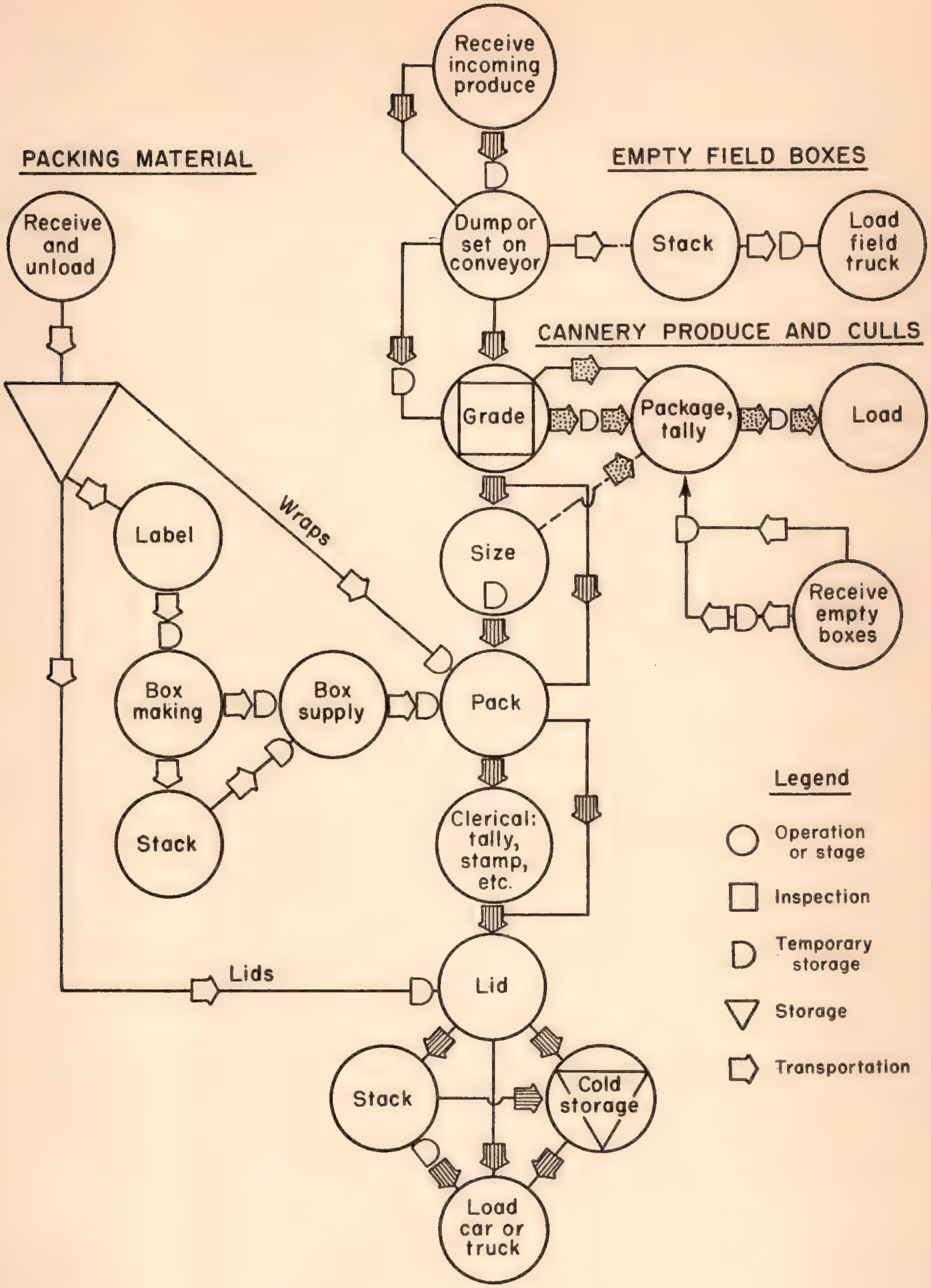
Receive incoming produce
PACKING MATERIAL
EMPTY FIELD BOXES
Receive and unload
Dump or set on conveyor
Stack
Load field truck
CANNERY PRODUCE AND CULLS
Grade
Package, tally
Load
Label
Wraps
Size
Receive empty boxes
Box making
Box supply
Pack
Stack
Clerical: tally, stamp, etc.
Legend
Operation or stage
Inspection
Temporary storage
Storage
Transportation
Lids
Lid
Stack
Cold storage
Load car or truck

Figure 1. Process Flow Diagram for Pear Packing Plants

(1) All packed fruit was assumed to be placed in standard pear boxes containing approximately 48 pounds net weight.

(2) No. 2 cannery fruit and culls (subgrade fruit) were assumed never to exceed 20 per cent of the total volume. This is typical of the average situation in the plants studied, although larger proportions were noted on some days. As No. 1 cannery fruit is packaged and transported in the same manner as No. 2 cannery and culls, this assumption influences only the costs of grading labor.

(3) Lidder operators were assumed to be paid by the hour. Typical piece rates result in higher cost in most ranges, although in a few instances, they might give slightly lower total cost.

(4) All packed fruit is assumed to be loaded in railroad cars.

(5) The major portion of the packing boxes are assumed to be made during the packing season at regular time rates of pay. The boxmaking operation was assumed to be integrated closely enough with box distribution so as to require little temporary storage and rehandling.

(6) Costs for miscellaneous labor, usually paid a fixed wage per day or per week, were converted to average hourly rates on the basis of an eight-hour day and a six-day week.

(7) Where rates of plant operation are specified, it was assumed that an essentially uniform rate of output per plant hour would be maintained throughout the season.

(8) The cost relationships shown in this report, originally calculated with 1950 wages and prices, have been adjusted to a 1954 level. Both wage rates and prices of buildings and equipment increased by roughly 16 per cent between 1950 and 1954. Since relative prices appear to have remained approximately the same and there have been no important technical innovations during this period, the relative efficiencies of the alternative technologies were also about the same in 1954 as in 1950.

(9) The wage rates used in estimating the costs of particular packing house jobs were selected as typical of those observed in the plants studied. The selected wage rates were in general modal rates and for some jobs tended to be slightly above the average. Standardized rates were also used for other variable factors such as electric power and gasoline. The fixed costs of equipment were estimated as an annual charge computed on the basis of a standardized percentage of the current equipment replacement cost.

Description of Technologies

Observation in the sample of plants studied indicated that there were important variations in technologies used in eight of the plant stages. Very briefly, they are as follows:[1]

Stage 1: Dumping[2]

Dumping consists of emptying the contents of field lugs on conveyors which carry the fruit to the grading tables. Five methods are considered in this analysis.

A--Hand dumping without conveyor aids. The dumper is unaided except for the possibility of alternating with a worker on a different job such as a trucker. The dumper obtains the full lug from a stack on the floor or pallet, empties the lug, and stacks the empty lug.

B--Hand dumping with conveyor aids. The field lugs are dumped by hand, but the dumper is aided by means of conveyors which carry full lugs to the height of the dumping station and which carry away empty lugs. The dumping crew consists of set-on men for full lugs, dumpers who tip the contents of the lugs onto the dumping tables, and setoff men for empty lugs.

C--Hand dumping with conveyor aids plus relief. The dumper and setoff men trade jobs periodically and an additional rest is given which allows them to operate at an accelerated pace while actually working.

D--Single box machine dumper. Full lugs are fed into a chain-type dumping machine which automatically dumps the contents and places the empty lug on an empty lug conveyor to the box yard. The dumping crew then consists only of set-on men for full lugs and setoff men for empty lugs.

E--Stack dumper. Full lugs are fed into the machine in stacks of five or six lugs. The machine automatically destacks the lugs one at a time, empties the contents, and places the empty lug on the empty lug conveyor. As the last box in the stack is dumped, a new stack is moved into place from a floor chain conveyor. A setoff man is required for empty lugs.

Stage 2: Grading[3]

The job of grading--inspecting the field-run fruit and separating it into grades for packing or for diversion to processing and cull uses--was essentially

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[1] More detailed descriptions are given in the references listed on the last page of this report.

[2] Sammet, L. L., Costs of Dumping Incoming Fruit as Related to Work Methods--Pear and Apple Packing Houses (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, June, 1953). (Giannini Foundation Mimeographed Report No. 153.)

[3] For more detail, see Bressler, R. G., and B. C. French, Grading Costs for Apples and Pears (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, June, 1952). (Giannini Foundation Mimeographed Report No. 128.)

the same in all the plants studied. However, four sizes of grading tables were observed in use.

A--A 14-foot table with capacity for 8 sorters.
B--A 17½-foot table with capacity for 10 sorters.
C--A 21-foot table with capacity for 12 sorters.
D--A 28-foot table with capacity for 16 sorters.

Stage 3: Packing[1]

Packing consists of placing fruit firmly and uniformly in boxes so as to avoid damage in transport and to present an attractive appearance to buyers. Three types of equipment are commonly used.

A--Canvas bins. The fruit drops into the bins from curtain or rope sizers and rolls down the sloping canvas bottoms to the packer. Bin boys are commonly used to keep the fruit piled up at the bottom of the bins where it is most convenient for the packers. In addition, they may push boxes on conveyors, occasionally set off packed boxes for packers, and give other minor assistance.

B--Tubs. Two types of tub packing equipment are used. They are the large 7½-foot diameter tubs arranged in a single row with access by packers on both sides and small 3-foot tubs arranged in double rows. Both types of tubs have spring-weighted bottoms that keep the fruit at convenient levels and both rotate in order to keep packers evenly supplied with fruit. Curtain or rope sizers are used with both sizes of tubs. Only the large-size tub is considered in this analysis. This size was more commonly used and both sizes show about the same level of costs.

C--Belts. The fruit is packed directly from conveyor belts on which the fruit circulates past the packers who select the particular size to be packed. Sizing equipment is not required as the operation is performed by hand selection simultaneously with the packing operation.

Stage 5: Lidding[2]

Lidding consists of nailing lids on packed boxes of fruit. Three types of machines are commonly used.

A--Stitcher. Boxes are pushed into the machine by hand and the machine drives two nails at a time--one on each end of the box. A total of three nails are usually driven in each end of the box.

B--Low-speed lidder. The operator pushes the packed box into the machine and inserts the lid. All nails are driven with one machine cycle. Most low-speed lidders are equipped with automatic ejectors for lidded boxes.

1/ For more detail, see French, B. C., Packing Costs for California Apples and Pears (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, October, 1952). (Giannini Foundation Mimeographed Report No. 138.)

2/ For more detail, see French, B. C., "Efficiency in Fruit Marketing," California Agriculture, vol. 35, no. 1, January, 1953, p. 10. (University of California, College of Agriculture, Giannini Foundation of Agricultural Economics.)

C--High-speed lidder. The operator feeds in the lids and the machine does the rest--carries the box into the lidder, lids, and ejects.

Stage 7: Boxmaking and labeling[1/]

Boxmaking consists of assembling and nailing together the boxes used to ship the packed fruit to fresh markets. Three types of machines are used for this operation.

A--Push through and side conveyor semiautomatic machines. All box shook is placed in the machine manually by the operator.

B--Automatic end feed machines. Box ends are fed into the machine automatically.

C--Fully automatic machines. All box shook is fed into the machine automatically and the box nailed together and ejected.

Labeling consists of pasting labels on the ends of the packing boxes, usually before the boxes are made. Detailed analysis of the alternative methods of labeling were not made, and costs for this operation are calculated at the usual piece rate for hand labeling.

Stage 8: Empty packing box and materials supply[2/]

This operation consists of placing pads and liners in packing boxes and moving them to the packers. Five methods are considered.

A--Elevate to mezzanine and line box. The empty box rolls on a gravity conveyor from the boxmaker to an elevator man who transfers the box to an elevator. The box is elevated to a gravity conveyor on a mezzanine where the boxes are nested, then set off and stacked. The stacked boxes are hand trucked to box liner stations above each packing line and are transferred individually to a bench where pads and liners are inserted. Boxes are then placed in chutes which feed the lined boxes to gravity conveyors running the length of the packing lines.

B--Line, then elevate to mezzanine. As the box rolls on a gravity conveyor from the boxmaker, pads and liners are dropped into place by a box liner. Each box is then hand transferred to an elevator. The box is delivered to a gravity conveyor on a mezzanine which extends across one end of the packing lines. On the mezzanine, the boxes are hand transferred to chutes leading to gravity conveyors that extend the length of each packing line.

1/ For more detail, see McCauley, Bruce G., "Boxmaking Methods and Costs," California Agriculture, vol. 8, no. 2, February, 1954, p. 2. (University of California, College of Agriculture, Giannini Foundation of Agricultural Economics.)

2/ For more detail, see Sammet, L. L., "Packing Box Distribution Costs," California Agriculture, vol. 9, no. 4, April, 1955, p. 3. (University of California, College of Agriculture, Giannini Foundation of Agricultural Economics.)

C--Hand truck to packing lines. The boxes are nested on a gravity conveyor leading from the boxmaker and then set off and stacked. Later the boxes are trucked to the end of the packing line. Here they are transferred individually to a bench where pads and liners are placed and each box is pushed down a gravity conveyor leading to the packers.

D--Monorail conveyor. Pads and liners are placed in each box as it rolls on a gravity conveyor from the boxmaker. The lined boxes are then transferred to hooks on an overhead monorail conveyor which carries the boxes through the packing area.

E--Box mezzanine. All the boxmaking and distribution operations are performed on a box mezzanine. Boxes roll on a gravity conveyor from the boxmaker to a box-lining station above each packing line. Each box is transferred to a bench, pads and liners are inserted, and the box is transferred to a chute which feeds lined boxes to a gravity conveyor running the length of the packing line.

Stage 10: In-plant transportation[1/]

The major in-plant transportation jobs are receiving incoming fruit and transporting to dumping stations, transporting cannery and cull fruit, transporting packed fruit from the lidder to the car, and transporting box shook and materials. Three types of transportation equipment are considered.

A--Hand trucks. For all transportation jobs.

B--Fork-lift trucks. For all transportation jobs.

C--Power conveyor. For packed fruit only.

Stage 16: Accounting to growers for fruit received at the packing house[2/]

Most plants handle fruit for a number of growers and a separate accounting must be made to each grower for the quantities of his fruit falling in each of several grade classifications. Two methods are commonly used for this purpose.

A--The separate-lot system. The identity of each grower's product is maintained until it is sorted, graded, sized, packed, and the amount in each grade determined. In order to prevent the mixing of fruit from several growers, each lot is run separately with a delay or break in the plant operations at the end of each lot. In addition to the direct cost of determining and recording the amount of fruit of several grades in each lot, the interruption of fruit flow has an impact on over-all plant output and efficiency and so on costs.

[1/] For more detail, see Sammet, L. L., In-Plant Transportation Costs as Related to Materials Handling Methods--Apple and Pear Packing (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, January, 1953). (Giannini Foundation Mimeographed Report No. 142.)

[2/] For more detail, see French, B. C., and R. G. Bressler, Economy and Accuracy in Accounting to Growers for Fruit Received at the Packing House (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, June, 1953). (Giannini Foundation Mimeographed Report No. 149.)

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[illegible]

[illegible]

[illegible]

B--The sampling system. Estimates of the proportion of fruit in each grower's lot are determined by sampling a small part of the fruit. This permits the fruit to be comingled in handling and thus eliminates interruption in changing grower lots. Accuracy increases with the size of sample, but this must be balanced against the increased sampling cost.

No completely general statement can be made as to the relative efficiency of sampling and separate-lot systems but available evidence suggests that the sampling system usually is the most efficient. This will be the only system considered in the present report. It is assumed that 5 per cent of the fruit is sample graded from each grower's lot. For the plants studied, this would give a limit of error in the estimates for the average grower of between 1/2 per cent and 1 per cent of the total weight of all fruit delivered per season (based on a probability of exceeding this limit once out of 20 times).

Other Stages

For the remaining stages listed on page 3, the technologies used were essentially the same among plants or the differences could not be clearly distinguished, and only one method was considered for each component.

Least-Cost Technologies

Since the several different technologies that might be used in a given stage involve different amounts of durable equipment, length of season has an important effect on relative costs. This is due to the decreasing average unit costs that result when hours of operation per season increase and the fixed costs of equipment are spread over a larger annual volume. Relative costs with different technologies may also be affected by rate of output per hour. These two factors, therefore, must be considered in selecting the appropriate technology in each stage.

The results of studies of costs in relation to length of season and rate of output per hour with the alternative stage technologies described above are summarized in Figure 2. For eqch stage, the appropriate technology is indicated by the area in the diagram corresponding to specific lengths of season and rates of output. To illustrate the use of Figure 2, consider a plant which operates 200 hours per season and has a total capacity of 50,000 pounds per hour, of which 40,000 pounds per hour is packed. The least-cost combination of technologies would be found as follows. Entering the chart (upper, left) in Figure 2 with 200 hours of operation per season and a capacity rate of 50,000 pounds per hour indicates that hand dumping without conveyor aids (method A) will result in lowest cost. In a similar way, the other diagrams indicate

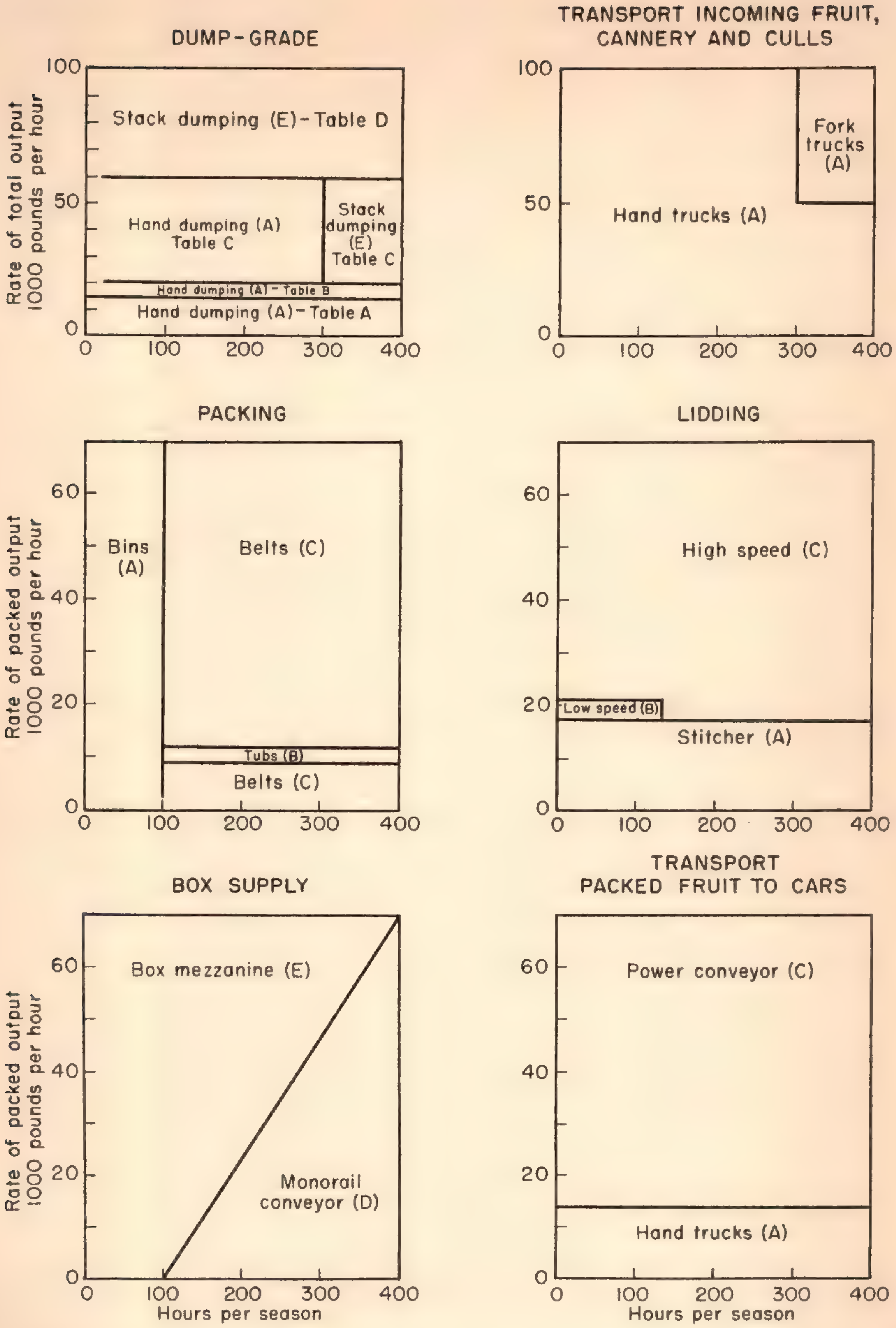

Figure 2. Technologies Having Least Total Cost for Given Plant Capacity and Hours of Operation Per Season

that least-cost technologies for the other stages would be: grading table C; hand trucks for transporting incoming fruit (method A); belt-type packing equipment (type C); the high-speed lidding machine (type C); boxes made and supplied from a mezzanine (method E); and packed fruit transported to cars by power conveyor (method C).

Of the alternative technologies previously described, dumping methods B, C, and D and box-supply methods A, B, and C do not appear in the diagram in Figure 2. This means that other technologies shown in the diagram give lower costs for all rates of output and hours of operation per season.

While Figure 2 indicates the selection of stage technologies on the basis of costs in relation to rate of output and length of season in packing pears, several other considerations may have an important influence on the method chosen for a given plant. With dumping methods B and C, for example, the conveyor aids make the job easier and so more attractive which may facilitate labor recruitment.

In many cases, some items of equipment may be used in packing other fruit at different times of the year. Equipment selection then would be made on the basis of total hours of use on all fruits. For example, if fork-truck equipment were used for only 150 hours per season to receive incoming fruit in a pear-packing plant, the chart (upper right, Figure 2) would indicate the selection of hand-truck equipment. However, if the use in receiving pears plus use on all fruits exceeded 300 hours per season and the average receiving rate on all fruits were more than 50,000 pounds per hour, the use of fork-truck equipment would be indicated.[1/] While not shown by the diagram, a similar example applied to a pear-packing plant operating 300 hours per season (with an additional 300 hours' operation on other fruits) would indicate the fork-truck equipment to be the most economical even in plants with small hourly capacities.

The selection of least-cost methods shown in Figure 2 is based on cost estimates which assume ownership of equipment by the packing house. With some types of equipment--for example, fork trucks and boxmaking machines--rental rather than ownership may permit economical use of the more highly mechanized

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[1/] Shifting equipment to other uses is particularly practicable with equipment not specially designed for a given crop. This is generally true, for example, with in-plant transportation equipment. Other equipment, such as boxmaking and lidding machines, is easily adapted to use with different kinds of fruit. Where harvest seasons do not overlap, such equipment may even be shifted from one plant to another.

methods at lower output rates or with shorter operating season than shown in the diagrams.[1]

In addition to possible alternative uses for equipment, there may be, in some instances, reasons for selecting a given method that are not easily measured in terms of costs. The choice of transportation method may be affected by such considerations. To illustrate, the costs of transporting incoming fruit are lowest with hand trucks (method A) if the equipment is used only for pears and the length of season is 200 hours or less. With 300 hours of operation per season, costs with fork trucks and hand trucks are about the same, but when the transportation job is considered jointly with the dumping-grading stage, hand trucks again give the lowest estimated total cost. The difference, however, is fairly small with this length of season and the unmeasured advantages of fork-truck operation--more rapid unloading of grower trucks, easier adjustment to short-period overload in deliveries of produce, and reduced damage to the fruit--might easily swing the balance in favor of fork trucks.

An illustration of how considerations other than measured costs may be of importance is found in the packing stage. Figure 2 shows that, for most rates of output and lengths of season, the selection of type of packing equipment lies between bins (type A) and belts (type C). A comparison of costs with all three types of equipment shows, however, that there are some rates of output at which costs with tubs (type B) are only slightly higher than with the belt equipment. Some managers may expect the mechanical sizing used with the tubs to be more consistent than the hand sizing with belt-type equipment and, for this reason, prefer the slightly more costly method. Another consideration is that less experienced packers may be required with tub- or bin- than with belt-packing equipment, and this may be important if experienced packers are in short supply.

PEAR PACKING PLANT COSTS

The relationships illustrated in Figure 2 between rate of plant output, hours of operation per season, and the most economical stage technology are based on standards of labor and equipment requirements and costs derived from studies of actual packing house operations and from accounting record data.

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[1] For further discussion, see Sammet, In-Plant Transportation . . ., p. 43.

These standards have been published for specific plant stages in earlier reports in this series and form the basis of the cost analysis that follows.[1]

Plant Specifications

A set of summary specifications for three efficiently organized plants is given in Table 1. The plants are 15,000-, 40,000-, and 70,000-pounds-per-hour total capacity with 70 per cent packed fruit, 10 per cent first-grade cannery, and 20 per cent second-grade cannery fruit. The plants are assumed to operate 200 hours per season. Table 1 specifies the crew required on the various jobs in each plant and lists the major items of equipment needed.[2] The labor and equipment requirements given in the table represent "efficient" combinations for the capacity rates of operation specified.

The capacity rates indicated in Table 1 are fixed in terms of the production standards for labor and equipment established in the studies referred to above. Since the packing process is essentially one of continuous flow, the capacity rate for the entire plant is limited by that on the "bottleneck" operation, and there will be some unutilized capacity on the remaining operations. This is true even with efficient organization since labor and equipment must be added in whole units and capacity rates on all operations cannot be perfectly harmonized.

In actual plant operation, some variation from the specified capacity rates would be possible. Downward adjustment in output rate could be accomplished easily by reducing crew size on some jobs or--in multiline plants--by operating fewer lines. Increasing output rates beyond the indicated capacity without modifying the plant layout and equipment would be more difficult. Minor upward adjustment might be attained for short periods through accelerating output on the bottleneck job beyond the normal rate. If carried very far, however, such expansion of output might induce sharply increased costs due to overloading equipment and crowding of labor.

Costs in Plants of Specified Scale

From crew and equipment specifications for different output rates such as given in Table 1, total costs with any desired rates of operation can be calculated. The results of such calculations, using standardized cost rates as

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[1] For additional information as to labor and equipment requirements and costs, see the earlier publications listed on the last page.

[2] *Ibid.*

TABLE 1

Labor and Equipment Requirements for Three Efficient Plants with 70 Per Cent Packed and a 200-Hour Season[a]

	Crew organization				Equipment requirements[b]			
		Number of workers				Number of units		
		Plant capacity, 1,000 pounds per hour				Plant capacity, 1,000 pounds per hour		
Stage or cost component	Job	15	40	70	Type of equipment	15	40	70
1. Dump	Dumper	1	--	--	Dumping table and elevator to grading table	1	1	2
	Set off empty lugs	--	2	3	Stack dumping machine	--	1	2
					Empty lug conveyor:			
					Power - 40 feet		1	2
					Gravity - 48 feet		1	2
2. Grade	Sorters	9	16	30	Grading table - 28 feet	--	1	2
					17½ feet	1	--	--
					Distribution belt - 30 feet	--	1	2
3. Pack	Packer	17	45	71	Tub packing line - 80 feet	1	--	--
					Belt packing line - 60 feet	--	3	5
					Packing stands	17	45	71
4. Tally	Packer tally	1	1	2	Tally desk, forms, pencils	1	1	2
5. Lid-stamp weight	Lidder operator	1	1	1	Stitcher type lidder	1	--	--
					High-speed lidder	--	1	1
	Check weight, stamp, place top pad	1	4	6	Bench scales	1	1	2
					Stamp stand and stamps	1	1	2
6. Carload	Carloaders	1	3	5	Car squeeze	1	1	1
					Ramps	1	2	4
					Hammers (in miscellaneous equipment)			
7. Boxmaking and label	Assumed to be on contract basis							
8. Empty packing box supply	Box men	1	2	5	Monorail conveyor - 100 feet	--	4.2	--
					Gravity conveyor - 35 feet	2.2	--	10
					Work table and box chute	1	--	4
9. Package cannery	Box fillers	2	5	8	Cannery and cull conveyors	[c]	[c]	[c]
10. Transportation	Truckers	5	10	16	Hand trucks	5	10	16[d]
	Set off packed boxes	1	--	--	Power conveyor - lidder to car	--	[e]	[e]
	Conveyor men	--	1	1	Gravity conveyor - lidder to car	--	[e]	[e]
11. Miscellaneous labor	Foremen	2	3	4	No equipment			
	Nightmen	1	1	2				
	Seasonal office clerks	2	2	3				
	Weighmaster[f]	1	1	1				
	Utility	1	2	3				
12. Office and administrative labor	Manager	1	1	1	No equipment			
	Bookkeeper		1	1				
13. Miscellaneous equipment	No labor				Small tools, office equipment, etc.	[g]	[g]	[g]
14. Building	No labor				Floor space - square feet[h]	15,900	30,900	48,600
15. Miscellaneous general costs	No direct labor				No equipment[i]			
16. Accounting to growers for fruit received	Sampling labor	2	4	7	Sampling table	1	1	1
					Bench scales	1	1	1
					Hand truck	1	1	1
Total crew		50	105	170				

[a] Of the total output, 10 per cent is No. 1 cannery and 20 per cent No. 2 cannery and culls. For purposes of conversion from pounds to lugs, field lugs are figured at 44 pounds each.

[b] Includes only the major items and specifications.

[c] For more detailed specifications, see L. L. Sammet and I. F. Davis, Building and Equipment Costs, Apple and Pear Packing, California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, Mimeographed Report No. 153, 1953, p. 37.

[d] Fork trucks might be used in this plant to advantage with little increase in cost--see discussion in text. Equipment requirements would, of course, differ.

[e] Details on the types of conveyors and transportation distances are given in L. L. Sammet, In Plant Transportation Costs as Related to Material Handling Methods, Apple and Pear Packing, California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, Mimeographed Report No. 142, 1953, p. 10 and p. 50.

[f] Combined with the duties of a trucker in small plants.

[g] For more detailed specifications, see Sammet and Davis, op. cit., p. 37.

[h] See Sammet and Davis, op. cit., for further details.

[i] Includes office and general supplies, auditing and legal expense, and insurance on inventories.

described on page 2, are given in Figure 3. Part A of Figure 3 shows the relation between rate of output and total costs per season (including the costs of both labor and the variable and fixed costs of equipment) while Part B of the diagram converts these total costs per season to average costs per 1,000 pounds of fruit. The costs of packaging materials are excluded since they did not appear to be affected by quantity of output within the volume ranges of the plants studied. Materials costs in 1954 averaged about 60 cents per standard pear box.[1] If this cost were added, it would merely raise the level of costs without significantly affecting the cost relationships developed in this analysis.

In both parts of Figure 3, two types of cost relationships are presented. The solid line in each chart shows the effect on costs as rate of output per hour is varied in the particular plants with 15,000-, 40,000-, and 70,000-pounds-per-hour capacity as specified. Such curves reflect the relationships that apply to an existing plant in which the equipment and physical layout of the plant are already established and certain costs are fixed but in which some adjustment in the use of labor and other variable factors is possible as the output rate of the plant is varied. Many other such curves representing costs in plants of different size could be drawn. A line traced through the lower limits of such curves then would show relation between costs and scale of operation in efficiently organized plants of any size within the volume range shown. This least-cost curve--the light dashed line in Figure 3--is referred to as the "planning curve" since it is of major importance in the problems of selecting optimum combinations of technologies and size of plant that arise in planning new plant facilities.

As rate of output increases in these particular plants, total costs increase uniformly until plant capacity is reached. Average costs, on the other hand, decline as output rate increases until plant capacity is reached. This is due to spreading the costs of fixed items of equipment and buildings and the partially "fixed" labor elements (such as foremen) over greater volumes of output. In each plant, the costs at low rates of output are well above those shown by the planning cost curve. As rate of output increases, however, the cost curves for the given plants and the planning cost curves move closer together and they converge at the plant capacity rate. The costs indicated at

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[1] With 48 pounds of fruit per standard box and 70 per cent packed fruit, the materials cost amounts to approximately $8.75 per 1,000 pounds total fruit run.

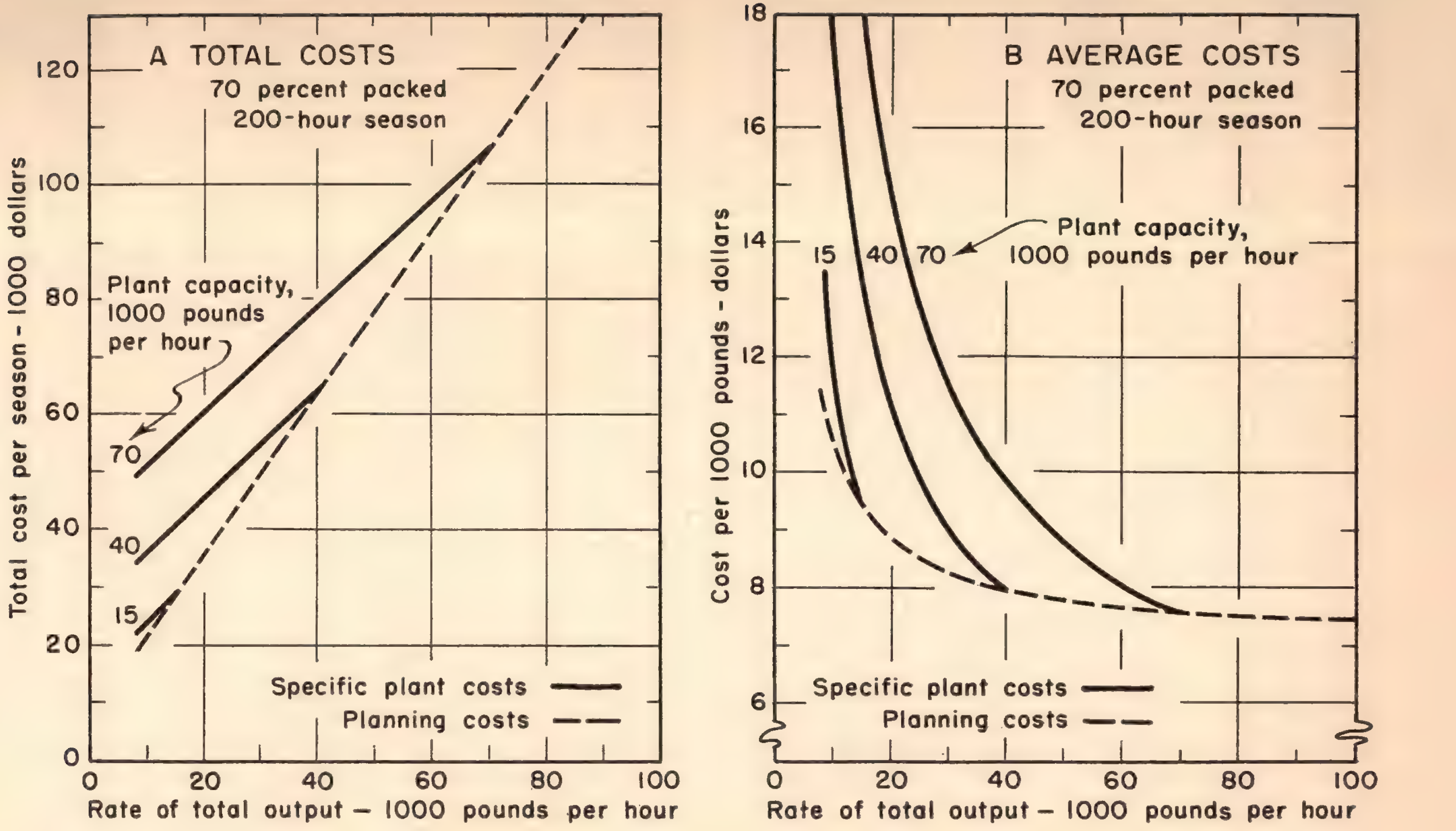

Figure 3. The Relation Between Planning Costs and Rate of Total Output in Efficient Plants of 15, 40, and 70 Thousand Pounds Per Hour Capacity, 70 Per Cent Packed Fruit, and 200 Hours of Operation Per Season (Materials Costs Excluded). Costs Based on 1954 Level of Wages and Prices

such points--and at all other points on the planning cost curve--are the minimum attainable with the kinds of technology presently available.

As indicated in Figure 2, the major changes in costs due to shifting to more highly mechanized technologies have been exhausted by the time plants reach a capacity of 25,000 pounds per hour. Thereafter, increased capacity is obtained primarily by multiplying the number of units of similar types of equipment. Thus, for the larger plants, the curves relating total costs and rates of output in individual plants tend to have about the same slope and variable operating costs per unit of output are nearly constant as size of plant increases.

Effect of Scale of Operations on Costs

The planning cost curves shown in Figure 3 apply to situations where 70 per cent of the fruit is packed (the average proportion for the sample of plants studied) and the plants operate 200 hours per season. Changes in the proportions of packed and cannery fruit and in the hours operated per season also have an impact on costs. The approximate relation between the planning costs and these several factors may be expressed by the following equation:

$$T = \$3,226 + \$18.5H + \$507P + \$371C + \$6.06PH + \$1.81CH$$

where T is the total operating cost per season in 1954 dollars (excluding materials), P is the capacity output of packed fruit in 1,000 pounds per hour, C is the capacity to handle cannery and cull fruit in 1,000 pounds per hour, and H is the total hours of plant operation per season. This is simply an algebraic way of indicating how total costs change with changes in plant capacity (both packed and nonpacked fruit) and with hours of operation per season.

To illustrate, if plant capacity is 40,000 pounds per hour packed and 10,000 pounds of cannery and cull fruit, the equation may be reduced to:

$$T = \$27,206 + \$279H$$

In other words, total costs per season for plants of this size are a minimum of \$27,206 even if the plant operates on a very restricted basis, and they increase by \$279 for each increase of one hour in the length of the season (and 50,000 pounds in total season volume of fruit). On the other hand, if operating time is a constant at, for example, 100 hours per season and rate of output per hour is allowed to vary, the equation simplifies to:

$$T = \$5,076 + \$1,113P + \$522C$$

Under these assumptions, total costs per season are at least \$5,076 and increase by \$1,113 with each increase of 1,000 pounds in packing capacity and by \$552 for each increase of 1,000 pounds in capacity to handle cannery and cull fruit. The equation is not applicable to plants outside the capacity range of 5,000 to about 100,000 pounds of fruit run per hour.

The above equations have been used to compute costs in relation to rate of plant output, hours of operation per season, and the proportions of packed and cannery fruit as shown in Figure 4. Costs per 1,000 pounds of total output are given with 60, 70, 80, and 90 per cent packed fruit. With each percentage of packed fruit, a separate cost curve is presented for 100, 200, 300, and 400 hours of operation per season. Each such curve is a "planning" or "economies of scale curve" which shows the reduction in average cost (under

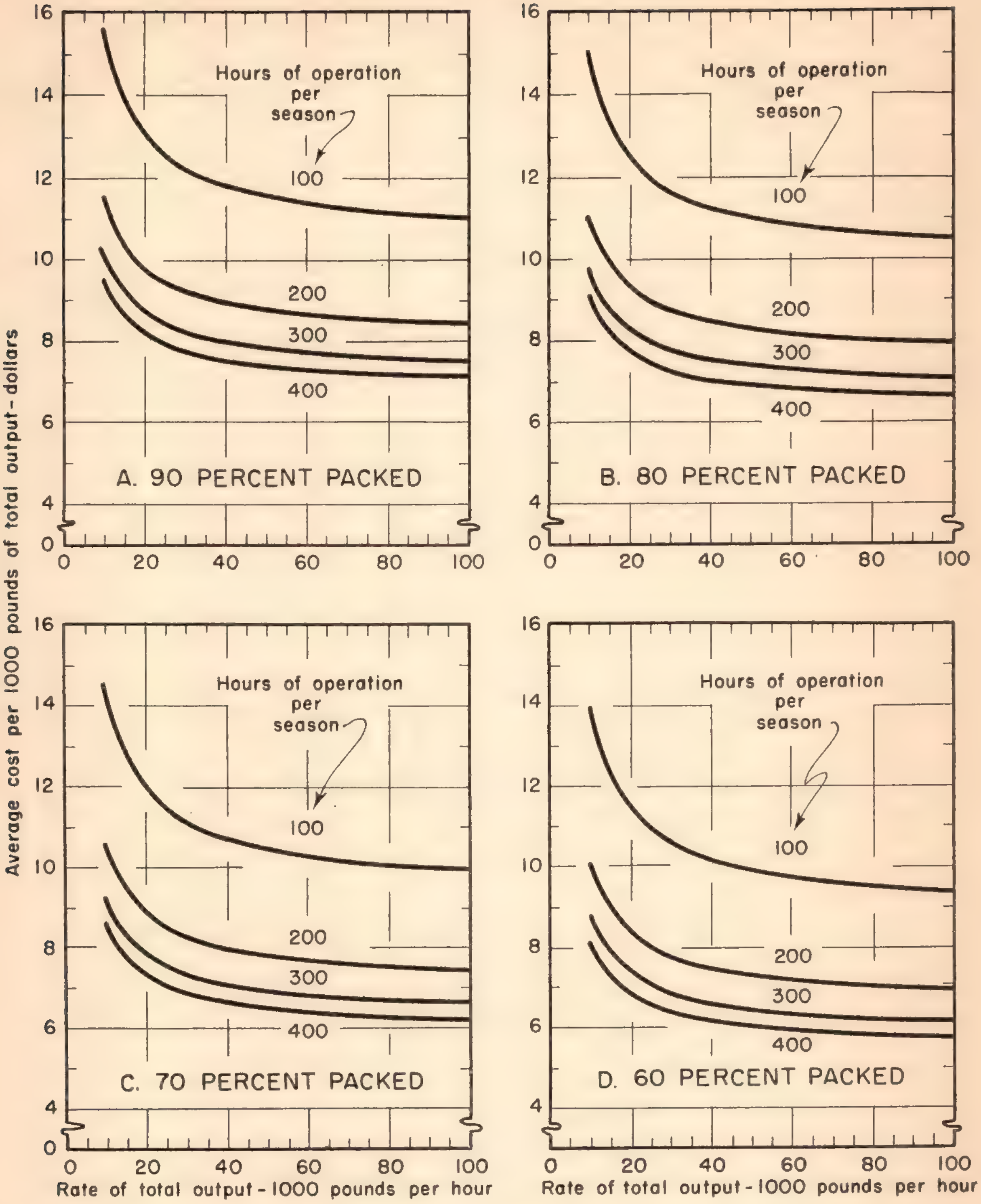

Figure 4. The Effect of Capacity Rate of Output (Size of Plant) and Per Cent of Packed Fruit on Planning Average Cost Per 1,000 Pounds (Materials Costs Excluded). 1954 Price Level

each specified set of operating conditions) as rate of plant output increases. The costs shown are based on the assumption that the plants operate at the specified rates for the number of hours per season indicated and that no overtime wage payments are involved.

The economies of scale curves show that, with small capacity plants, costs drop rapidly as size of plant increases. However, this effect decreases rapidly and is not important in the larger plants. For example, with 70 per cent packed fruit and 200 hours of operation per season, average cost at a plant capacity of 15,000 pounds per hour falls 15.4 cents with each 1,000 pounds per hour increase in planned capacity. At a plant capacity of 20,000 pounds per hour, this figure is 8.7 cents and, at 50,000 pounds per hour, it is only 1.4 cents per 1,000 pounds added capacity.

Figure 4 also shows the effects on costs of increasing season volume in a plant of given size by operating more hours per season. For any given capacity output rate, substantial reductions in average cost are indicated as the length of season is increased from 100 to 400 hours. This results entirely from spreading fixed costs per season over larger season volumes of fruit, for variable costs per hour are constant.

Effect of Two-Shift Operation on Costs

One means of obtaining at least part of the cost advantage of longer seasons would be to operate smaller plants on a two-shift basis. Although this might involve practical difficulties in recruiting labor and maintaining satisfactory labor relations, it appears to offer enough advantage under some conditions to be worth considering. If it were reasonable to assume that an extra shift could be operated with no increase in wage rates and other costs, an indication of its effect on costs could be obtained from Figure 4. Consider, for example, a plant designed for an 8-hour-per-day operation through a 200-hour season at a rate of 40,000 pounds of fruit run per hour, 70 per cent of which is packed. The season total volume would be 8,000,000 pounds, and the average cost would be about $8.00 per 1,000 pounds. With two-shift operation and the same harvest season, this volume of fruit could be handled in 400 hours' operation by a plant with a capacity of 20,000 pounds per hour and at an average cost of about $6.80 per 1,000 pounds.

To assume no change in cost rates with two-shift operation is somewhat unrealistic so that the above comparisons are not entirely valid. Adjustment of the costs shown in Figure 4 to allow for increased storage requirements for incoming fruit and for a 10 per cent higher wage rate for the second shift

[illegible]

The costs shown are based on the assumption that the plants operate at the indicated rates for the number of hours per season indicated and that no overtime wage payments are involved.

The curvature of the cost curves show that, with small capacity, [illegible] rapidly, [illegible] ity and is not important in the larger plants. For example, [illegible] packed fruit and 700 hours of operation per season, [illegible] capacity of 75,000 pounds per hour is the 12.1 cents [illegible] hour increase in planned capacity. At a plant capacity of 60,000 pounds per hour, this figure is 0.7 cents and, at 90,000 pounds per hour, it is only 0.4 cents per 1,000 pounds sealed capacity.

Figure 4 also shows the effects on costs of increasing season volume in a plant of given size by operating more hours per season. For the plant with each output rate, substantial reductions in average cost are indicated as the length of season is increased from 500 to 800 hours. This result, without the [illegible] cents per sector over longer [illegible], the variable costs per hour are constant.

[illegible]

One means of obtaining at least part of the cost advantages of larger [illegible] [illegible]. Although this would involve practical difficulties in recruiting and maintaining satisfactory labor relations, it appears to offer enough advantage to be [illegible] to be worth consideration. If it were reasonable to assume that an [illegible] could be operated with no increase in wage rates for the other shift, an indication of the effect on costs could be obtained from Figure 4. Consider [illegible] a 500-hour season at a rate of 40,000 pounds of fruit run per hour, 70 per cent of which is packed. The season total volume would be [illegible],000,000 pounds, and the average costs would be about $3.00 per 1,000 pounds. With two-shift operation and the same harvest season, this volume of fruit could be canned in 500 hours' operation by a plant with a capacity of 20,000 pounds per hour and at an average cost of about $6.80 per 1,000 pounds.

To assume no change in cost rates with two-shift operation is somewhat unrealistic so that the above comparisons are not entirely valid. Adjustment of the costs shown in Figure 4 to allow for increased storage requirements for incoming fruit and for a 10 per cent higher wage rate for the second shift would increase the costs with two-shift operation in the above example from \$6.80 to roughly \$7.50 per 1,000 pounds of fruit run.[1] Much of the advantage of the two-shift operation thus is lost if cost rates are increased for the second shift, although a moderate saving still is indicated under the modified assumptions.

Effect of Overtime Pay on Costs

In many California pear packing plants, workers are paid at one and one-half times the regular-time rate for work in excess of eight hours per day.[2] This does not materially alter the major conclusions and cost relations that have been indicated, but it may affect the optimum plant size and season hours of operation for handling any given season volume of fruit. The increased pay rates for operation in excess of eight hours per day tend to make larger plants with shorter days relatively more economical.

Incorporation of the overtime pay considerations in the previous analysis indicates that, for seasons of 25 days or more, planned overtime operation is not efficient. The costs of handling a given season volume can be minimized by constructing a plant designed to operate at not more than eight hours per day, except for unpredictably heavy deliveries or unusual market situations.

With seasons of less than 25 days, however, some overtime operation becomes economical. The advantages of handling a given season volume with lower fixed investments more than offset the disadvantage of the overtime pay rates. The average amount of overtime operation that will be economical depends on the number of days of operation and the total volume of fruit to be handled. With a season of 20 days, overtime operation would be economical for volumes greater than 5,000,000 pounds per season. For 7,500,000 pounds per season, costs would be minimized with an average of about one hour of overtime per day. This increases to two hours per day with 10,000,000 pounds total output per season.

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[1] Possibilities of reduced productivity in the second shift are assumed to be small or to be allowed for in the higher costs based on increased pay rates. Equipment repair expense per hour of use is included in the estimates of variable costs. This allows for the increased wear due to the more intensive equipment use in two-shift operation. Fixed costs of equipment are assumed not to be materially changed.

[2] Agricultural operations are exempt from overtime pay requirements during a 14-week period. Some pear packing plants take advantage of this provision--but many, because of union agreements or competition for labor supplies--pay one and one-half times the regular-time wage rate for all work in excess of eight hours per day.

[illegible] 1/ [illegible]
of the two-shift operation than in [illegible] if cost rates are increased for the second shift, although a moderate saving still is indicated under the modified [illegible].

[illegible]

In many California prune packing plants, workers are paid at one and one-half times the regular-time rate for work in excess of eight hours per day. 2/ This does not materially alter the major conclusions and cost relations that have been indicated, but it may affect the optimum plant size and longer hours of operation for handling any given season volume of fruit. The increased pay rates for operation in excess of eight hours per day tend to make larger plants with shorter days relatively more economical.

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2/ Agricultural operations are exempt from overtime pay requirements during [illegible] provisions but many [illegible] of union agreements or competition for labor supplies--[illegible] one and one-half times the regular-time wage rate for all work in excess of [illegible].

A significant characteristic of plants planned for operation in the overtime area is that there are wide volume ranges where costs remain fairly uniform due to a balancing of the higher overtime cost rates against the reduction in fixed investment per unit of output. This is illustrated in Figure 5 in which the average costs of handling season volumes of 5,000,000, 10,000,000, and 15,000,000 pounds are given in relation to hours of operation per season. The chart is based on the assumption that 70 per cent of the total fruit volume is packed and that the length of season is 30 days. The limitation on length of season means that 240 hours is the maximum that could be worked on a straight-time, 8-hour-per-day basis. Hours worked in excess of this total would be on an overtime basis.[1] The planned hours of operation with a given season volume determine the size of plant. For example, with a season volume of 5,000,000 pounds and 100 hours of operation, the plant capacity required is 50,000 pounds per hour; with 240 hours' operation, it is approximately 20,800 pounds per hour; and with 300 hours of operation (60 hours of overtime), the plant capacity would be roughly 16,700 pounds per hour.

Figure 5 indicates that the average costs of handling a given season volume decrease throughout the range of straight-time operation as hours of operation per season increase.[2] The curves "break" at the season limit for straight time (240 hours) and average costs rise slowly as hours of overtime operation increase. The downward trend in costs through the straight-time range represents the balancing of two effects. As hours of plant operation increase, the smaller size plants required to pack a given season volume would tend to increase costs slightly, but this is more than offset by the lower fixed costs for buildings and equipment as plant size decreases. In the range of overtime operation, average costs rise as the result of the increased wage rates. It is important to note, however, that these costs rise only slightly over a

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1/ Due to unavoidable variations in the volume of fruit received daily, most plants will operate less than eight hours on some days, so that some overtime would be necessary in order to average eight hours per day for the season. Data from the plants studied, however, indicate that the amount of such overtime need not be large, and it can be ignored in the above analysis without significantly affecting the results.

2/ The costs shown in Figure 5 are based on the assumption that productivity during overtime and regular-time periods is the same. This seems justified by data from the plants studied. The slightly higher output rates by workers on incentive pay plans that were occasionally evident did not appear to be sustained for long enough overtime periods to be significant.

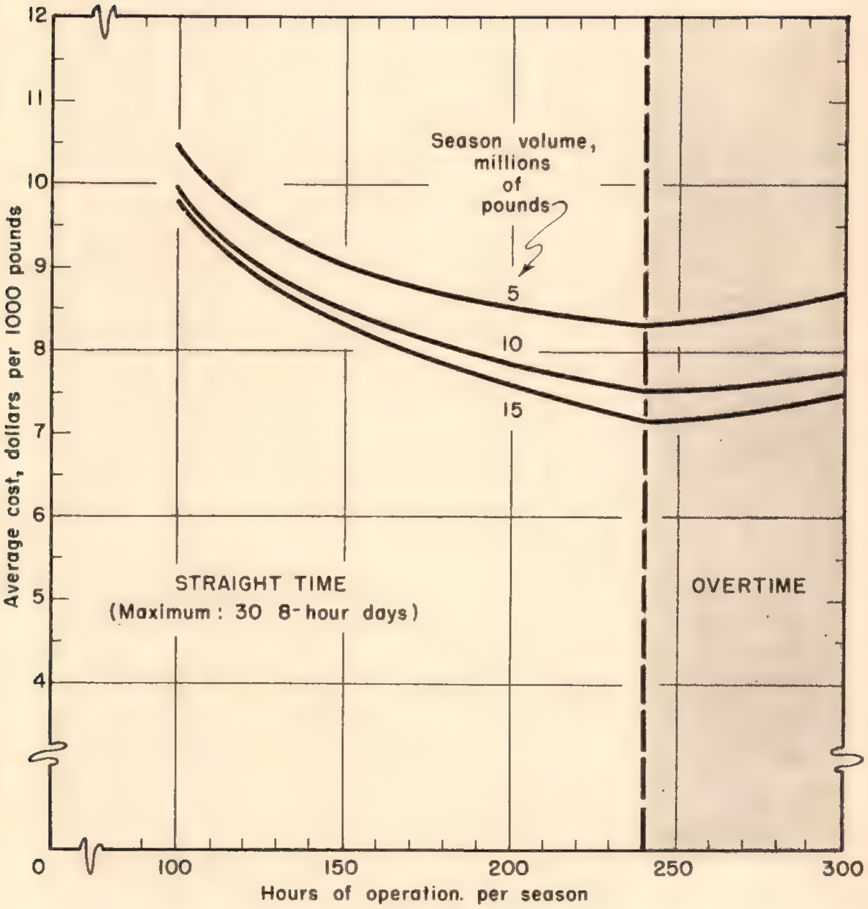

Figure 5. Relation Between Average Cost of Handling Given Season Volumes and Hours of Operation (With Corresponding Variations in Plant Capacity), Assuming a 30-Day Season and 70 Per Cent Packed Fruit (Materials Costs Excluded). 1954 Price Level

considerable range. For example, with a season volume of 10,000,000 pounds, plants designed to operate in the range of 240 to 280 hours per season would involve roughly the same average season cost. This means that, if a plant manager misjudges and builds a plant too small to handle his season volume without overtime operation, the penalty in higher costs is not very great. And if an error is to be made, the diagram suggests that it is better to underbuild than to overbuild since the rise in average costs is less rapid with expansion beyond the straight-time limit of 240 days per season than for movement in the direction of shorter seasons. With short-season operation (less than 25 days), some overtime operation will give lower average cost (see page 22).

Optimum Combinations of Season Hours and Plant Capacity

It is clear that any given season volume of fruit can be handled by many different combinations of plant size and hours of operation and that the particular combination used will affect costs. Such restrictions as local customs, practices regarding overtime pay, and the length of harvest season place limits to the possible combinations, yet, permit much variation. The problem is to find the particular combination of hours of plant operation and rate of output that gives the lowest total cost for handling any given volume of fruit per season. In view of the uncertainties in planning operations over a time period, this solution should also allow for flexibility that will give relatively low costs over a range of output rates near the optimum point.

While all possible combinations cannot be considered in this report, three important alternatives are illustrated in Figure 6. Two sets of curves are presented, one based on a harvest season of 20 days, the other on a harvest season of 30 days. In each diagram costs per 1,000 pounds of fruit run are shown in relation to total season volume of fruit handled and for three different assumptions as to hours worked per day and as to overtime payments. The three cases presented are: (1) one 8-hour shift per day for the entire season; (2) two 8-hour shifts per day, with allowance for additional costs in storing incoming fruit and for wage rates in the second shift 10 per cent higher than for the day shift and (3) overtime pay at one and one-half the regular rate for all work in excess of 8 hours per day. In computing the cost relationships shown in Figure 6, the length of the packing and harvest season was assumed to be the same, that is, there is no storage of field-run fruit. The least-cost combination of season volume, hours of operation per season, and plant capacity

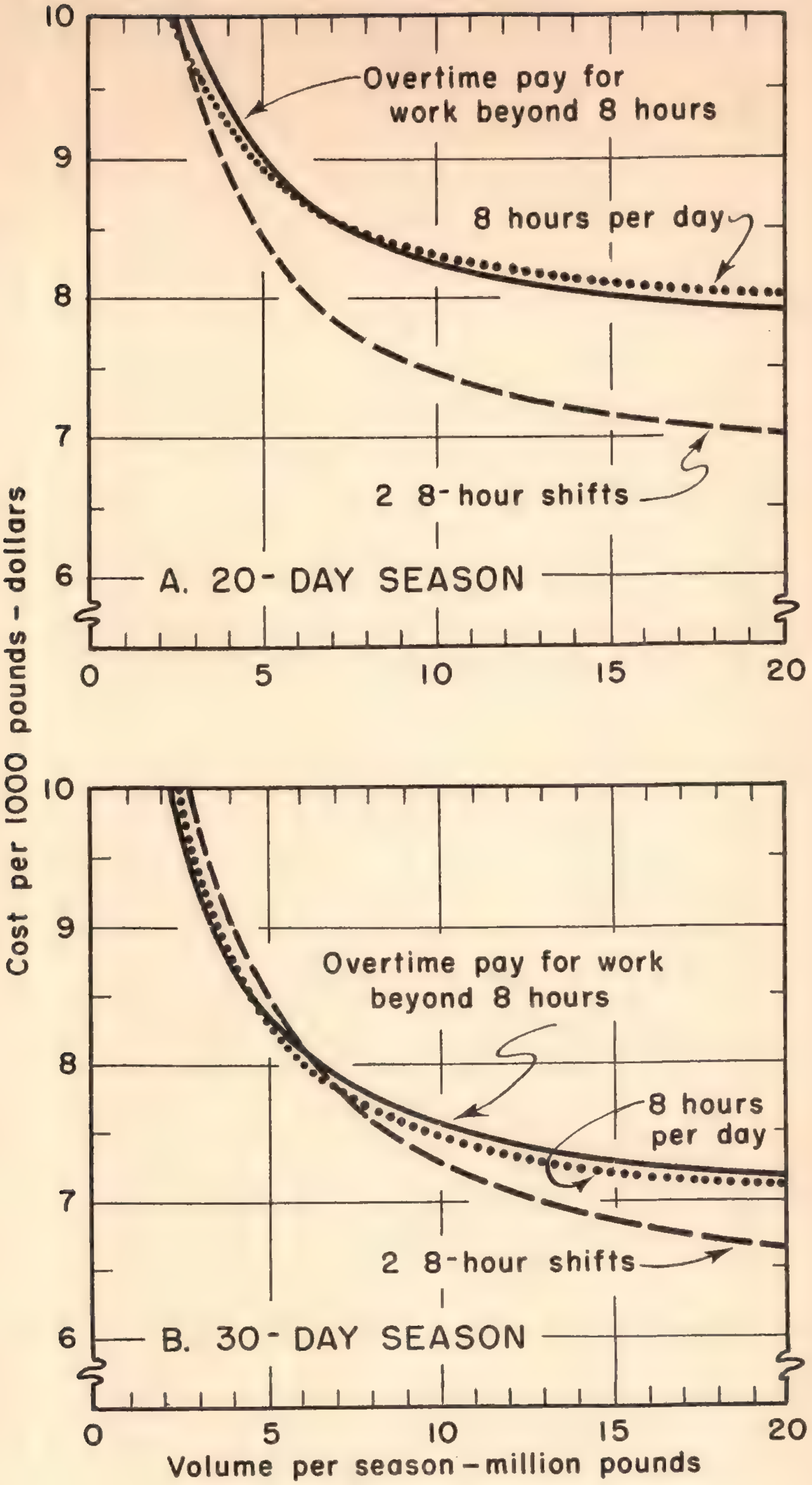

Figure 6. Relation of Average Cost to Season Volume for Three Operating Situations, and Two Lengths of Season (70 Per Cent Packed Fruit, 1954 Price Level, Materials Costs Excluded)

rates was worked out for each case. With relatively low-season volumes, this involves plant designs such that season hours of operation are in the ratio of 25 hours to each 1,000 pounds of plant capacity per hour.[1] Maintaining this ratio with low-season volumes requires operation for less than the maximum hours per season specified but, as season volume increases beyond a critical point, the plants are designed to operate for the maximum hours available and season volume is increased by increasing plant capacity rate.

The charts indicate that, for seasons as short as 20 days, the two-shift operation gives lower costs than both of the other situations considered. The results are different, however, with the 30-day season. Two-shift operation is lowest in cost for season volumes greater than about 7,000,000 pounds. Costs with a straight eight-hour-per-day limit and with overtime pay for work beyond eight hours are nearly the same for season volumes greater than about 5,000,000 pounds. For smaller season volumes, overtime operation is lowest in cost.

Problems of Flexibility

One of the important problems in pear-packing operation is how to adjust economically to considerable fluctuations in daily volume of fruit received throughout the packing season. In most cases, output increases fairly rapidly during the early days of the season, levels off near the peak, and then declines rapidly at the end. In some instances, a small volume of production may continue for a number of days at the end of the packing season. In the plants studied, about 75 per cent of the total hours per season represent operation at full capacity rates. Rates of output for the remaining 25 per cent of the time varied within and among plants but averaged about half of the capacity rates.

Two types of adjustment to such variations in output are used. In one, hours of daily operation may be varied and the plant operated at its most efficient rate of output with little change in cost rates, except where overtime pay is required (see the previous discussion). A second type of adjustment is applicable where there is a large reduction in daily volume relative to total plant capacity. The total labor force then might be reduced and the plant operated at less than capacity rates. This is particularly true if legal restrictions and the maintenance of satisfactory labor relations (including holding the crew) require that workers be paid for a minimum number of hours.

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[1] Derived from the cost equation on page 19.

Calculation of costs for several plants having some flexibility in regard to "efficient" output rates indicate that costs are higher in such plants than in plants operating at constant output rates. For the average variation observed in the plants studied--approximately 25 per cent of the hours at one-half capacity--these calculations show total costs to be from 1 to 4 per cent higher with variable than with constant rates of output.

Variation in within-plant rates of operation, while causing increased total costs, apparently has little effect on the selection of technologies--at least for the range of variation noted above. Costs with variable rates of output were calculated for a dozen or more "borderline" cases where it appeared that the need for flexibility might cause a shift to a different technology. In each case, however--holding volume per season at a particular level--the same technology proved to be most efficient for both constant and variable rates.

Differences were noted in the relative costs among the alternative technologies with flexible and constant rates, but the differences were not great enough to cause a shift in the least-cost technology. Under some other circumstances, it may be expected that the methods that are most economical for pear plants with variable rates will differ from those with constant rates. The amount of cost difference involved will generally be small, however, and there is no great penalty for building a plant in terms of constant rate specifications even though the rates may actually vary. Nearly all technologies provide a considerable amount of flexibility.

This suggests that the combinations of technologies indicated in Figure 2 as optimum with operation at the rates specified may give fairly close approximations to the technologies that would be most efficient for the amount of variation in output rates that appears to be typical for pear packing plants. In applying the diagram to a situation in which output rates vary through the season, hours per season should be modified to read equivalent hours per season at capacity rates of operation. This is merely a way of converting output rates in the flexible plant to a volume base equivalent to the constant rate plant. For example, four hours at three-quarters capacity would be taken as three hours at full capacity.

In addition to the variation in total volume during the season, there is also some variation in the proportions of packed and cannery and cull fruit. For small variations in proportions (within a range of 4 to 5 per cent), the average proportions or rates of output of packed and cannery fruit may be

substituted in the planning cost curve (see Figure 4) with little effect on the estimates of plant costs. The values and standards on which the cost curves are based are themselves "averages" which permit such small ranges of variation around any given rate of output.

When there is a considerable range in proportions of packed and cannery fruit, extending for fairly long time periods, the planning cost curve based on constant proportions is no longer exactly appropriate. However, the cost of providing the plant capacity to handle such variations is again relatively small and does not alter the major conclusions of the analysis.[1]

POTENTIAL COST SAVINGS

The foregoing analysis has suggested that, aside from possible innovations, the principal sources of economies in pear packing are in (1) selection of efficient combinations of technologies and (2) increased scale of operations both in terms of larger plants and longer seasons or increased hours of operation per season. Comparison of the sample plants studied with the "optimum" indicated by the planning cost curves shows that some of the sample plants have achieved a considerable portion of these economies and are operating, on the average, with a relatively high degree of efficiency. This is particularly true in view of the short seasons and uncertainties concerning supplies of both fruit and labor. In some plants, however, the adoption of more efficient methods could reduce labor and equipment costs by 15 to 20 per cent.

The saving resulting from adoption of the methods most efficient in terms of the particular operating conditions in each of the sample plants would result in estimated average savings of about $1.45 per 1,000 pounds of fruit handled. Applying this figure to the estimated annual average volume for the industry (about 144,000 tons), the average annual savings would be more than $400,000 in 1954 dollars. Since the sample plants are not necessarily representative of the industry, this should be viewed as an indication of approximate magnitude, rather than a precise industry estimate.

Further savings may be possible through increasing total season volume per plant by consolidation of plants in districts where there is an excess of plants, some of which are uneconomically small. A complete statement of such

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[1] More precise estimates of costs for variable circumstances can be calculated from the detailed reports that have been cited and from a technical report by the authors entitled "Economic Efficiency in Plant Operations . . . ."

savings would require consideration of costs of assembly of the produce as well as of plant costs, but in most instances, the consolidation probably could be achieved without very large increases in assembly costs as the amount of volume change suggested is not large and production areas tend to be fairly concentrated in most districts. Potential savings for the industry in this category are estimated as about $120,000.

Since the average period of operation per season in California pear packing plants is only about 200 hours, there are still some economies that might be achieved in this direction. If double-shift operation (and, consequently, further consolidation of plants) could increase the average period of operation per season to 300 hours, the cost savings for plants of 50,000-pounds-per-hour capacity would amount to about 50 cents per 1,000 pounds. Higher savings would be possible for smaller plants and slightly lower savings for larger plants. Average annual savings to the industry could amount to about $160,000.

The total of these potential savings amounts to roughly 20 per cent of the in-plant costs (excluding materials cost), although greater percentage savings would be possible in some individual plants. These savings could not be achieved at once, of course, particularly with regard to expansion in plant size.

SUMMARY

The objective of this report is to supply packing house managers with information on the effect of scale of operations on costs and on the combinations of methods or technologies that give least cost for plants of any given capacity rate of output or length of operating season. Details of crew and equipment organization are given for illustrative plants and the relation of cost to various rates of output are calculated for these plants.

The study indicates that average costs per unit of output decrease with increases in the scale of operations, both in terms of increased hourly plant capacity and in increased hours of operation per season. In terms of plant capacity, the major advantages of increased size are about exhausted when capacity rate of output reaches 50,000 to 60,000 pounds per hour, although some further reductions in average cost continue as plant size increases. Eventually, increased difficulties of management and coordination might reverse this trend, although this point was not reached in the present analysis. Increasing costs of assembly of the fruit would also impose limits on economical plant size.

An important problem considered is the determination of the particular combinations of plant capacity and hours of operation per season that give least cost for handling any given season volume.

With no storage of field-run fruit and with the customary restrictions on daily hours of operation, the hours of plant operation per season are, for all practical purposes, predetermined by the length of the harvest period. Expansion of total volume must then occur primarily through increased plant capacity.

Introduction of overtime pay requirements into the analysis tends to shift optimum hours and capacity rates slightly in the direction of larger plants and shorter hours per season due to the added costs of operation in excess of eight hours per day. For seasons of 25 days or more, the optimum plant would be of a size that could handle the required season volume with no overtime operation other than required to meet unexpected peak deliveries or special market situations. Under most circumstances, however, moderate deviations from this optimum size, particularly in the direction of smaller plants, do not affect costs greatly, for the added costs of overtime pay rates are partially balanced by the wider spread of overhead costs as hours of operation increase. For short seasons, plants of a size that would require some overtime operation may actually be the most economical.

Similarly, a plant that is ideally constructed for a given volume per season can handle moderate increases in volume with little change in average costs. The higher costs for the overtime operation necessary to handle the increased volume are almost exactly balanced by reduced average fixed costs due to spreading the fixed elements of cost over larger volumes. If the increased volume could be anticipated, however, a larger plant would give slightly lower average costs.

Another possible means of increasing hours per season is to operate two shifts per day. Reductions in average costs thus achieved through working more hours per season must be balanced against the added costs associated with two-shift operation. Cost comparisons indicate that two-shift operation offers some major advantages for plants with short seasons--20 to 25 days or less. But as the length of season increases, the cost advantages are reduced and may actually become cost disadvantages for plants with very long seasons and relatively small total season volume.

The study also indicates that the organization and equipment specified for plants represented in the planning cost curve in fact provide a considerable

amount of flexibility in adjusting to variations in total season volume. Although the principal means of adjustment is through changes in hours of operation per day, other types of adjustment are common. For example, with efficient adjustment in plant operation, average costs of labor and other variable inputs increase only slightly with operation at less than full capacity. This is particularly true where plants tend to be organized into a series of identical production "lines" which facilitate adjustment to major deviations from capacity operation. In such plants, for example, operation at half capacity may require little more than half the full labor crew so that only minor increases in average variable cost result from the reduced output rate. Packing plants are also adaptable to minor variations in the proportion of packed fruit, although to provide for large fluctuations may necessitate important amounts of excess capacity in some stages.

Although most pear packing plants in California have achieved a relatively high degree of efficienty, there are, aside from possible innovations in methods, two major types of adjustments which may lead to further cost reduction. These are (1) selection of efficient technologies which would bring costs in individual plants down to the level of the planning cost curve and (2) movement along the curve in terms of both increased hours of operation per season and larger, and consequently fewer, plants. Potential long-run industry savings are estimated to be about $420,000 per year for the first step and about $280,000 for the second step. This amounts to about 20 per cent of the in-plant packing costs (excluding materials). Although full evaluation of these savings would require consideration of costs of assembly and distribution as well as reductions in packing costs, plants tend to be closely located within producing districts so that a considerable amount of consolidation presumably could be accomplished without materially increasing assembly costs. For some individual plants, of course, the potential percentage reduction in costs is much greater than the 20-per-cent industry average.

While some of the potential savings could be achieved in the short run, most of the cost reduction possibilities involve changes in durable facilities which would be economical only as existing facilities are worn out. With technology changing over time and with many institutional barriers to some of the suggested changes, it is doubtful that more than a part of these savings can actually be attained. However, the material that has been presented should provide useful guides for packing plant operators interested in planning new or modernized facilities and for groups of plants contemplating reorganization and consolidation.

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